

StatsCasts: supporting student learning of introductory statistics

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With the diversity in the backgrounds of students currently entering universities, many students lack the preparedness to undertake studies that include quantitative content. At the same time, many of these students are required to enrol in an introductory statistics course at some stage during their undergraduate program of study. This, along with an associated prevalence of statistics anxiety, means that many students require additional assistance to progress and stay engaged. A variety of support mechanisms may need to be enacted to assist students to succeed. This paper introduces and discusses the development of StatsCasts: short, focused screencasts on topics students have struggled with in the past, for anywhere, anytime support in learning statistical concepts. An evaluation of the pilot stage of a larger research project is presented, to show how students at one of the three collaborating universities perceive these multi-media support resources, and to what level students access them. Initial findings indicate that most students found the StatsCasts beneficial to their learning and understanding of the relevant concepts.

1. Introduction and background

As the need for statistically literate citizens is becoming more widely recognised, greater numbers of university students are required to enrol in statistics courses as a necessary part of their tertiary studies. Moreover, these students are primarily non-specialists from a diverse range of disciplines which include medicine, health sciences, business, psychology, social sciences, education, and engineering, to name just a few. In their review of statistical education, Tishkovskaya and Lancaster acknowledge that “teaching statistical courses is challenging because they serve students with varying backgrounds and abilities, many of whom have had negative experiences with statistics and mathematics” [1,p.2]. They further note that even though there is a critical need for statistically educated citizens, students at all levels lack interest when taking introductory statistics courses.

In Australia many students entering university are required to study statistics in their very first semester at university, yet they often come with very little or insufficient exposure to quantitative (including statistical and mathematical) concepts. This lack of requisite quantitative skills needed to be successful in such courses has been discussed elsewhere [2– 6]. With this in mind, Rylands and Coady [4] recommend that the impact of this diversity in student preparedness to study quantitative content at university needs to be recognised and extra assistance provided.

Taking these circumstances into consideration it is unsurprising that many students experience statistical anxiety. In developing a model for predicting statistics achievement, Onwuegbuzie noted that “anxiety interferes with performance by impeding students’ ability to receive, to concentrate on, and to encode statistical terminology, language, formulas, and concepts” making it difficult for them to solve statistical problems [7,p.1033]. Learning statistics can be likened to learning a foreign language, with the fear of statistical language being an important component of statistics anxiety [8,9]. Zeidner [10] found that statistics anxiety correlates with past history of negative experiences and poor performance in mathematics and a low level of mathematics self-efficacy.

In response to this lack of preparedness and prevalence of anxiety surrounding mathematics and statistics, most Australian universities provide students with avenues for upgrading their quantitative skills [11], such as one-on-one appointments, drop-in support, course-dedicated support classes, or university-wide generic skills programs [12]. While 32 of Australia’s 39 universities had formal dedicated mathematics or statistics learning support centres in 2007, many students still do not have easy access to such support [11], particularly those who study at a distance. With this in mind, the authors commenced a collaborative project between Swinburne University of Technology (SUT), the University of the Sunshine Coast (USC) and the University of Southern Queensland (USQ) to produce multi-media resources to address this shortfall.

One impetus for this project was the international research collaboration between SUT (Australia), Loughborough University (United Kingdom) and Limerick University (Ireland), leading to the production of the increasingly-successful resource collection MathsCasts [13,14] and the aspiration of doing likewise for students of statistics. MathsCasts are short screencasts of a tutor explaining in handwriting a mathematical concept, or how to solve a mathematical problem. They are produced with the aim to provide anytime support to students outside potential face-to-face support hours, but also to allow students to access online resources when they are off-campus. They are designed to complement existing face-to-face support rather than replace it. Further to this motivation was the perceived need for this type of flexible learning support for our students of statistics. Statistics and mathematics support at SUT is currently provided by a support centre where tutors are available at specified times for one-to-one but also for group support for mathematics and statistics. In contrast there is no dedicated support centre available to students at USC. The situation at USQ is somewhere between these two—a dedicated support centre exists but it provides support across all aspects of academic studies, with statistics support being just one component.

In addition to this diversity in the level of support available, the student cohorts taking statistics courses at the three universities for whom the early StatsCasts were originally developed also have a wide variety of backgrounds and levels of statistics covered in their courses. Engineering students are the focus at SUT; psychology, business, and science students at USQ; and health and science students at USC. Furthermore, the majority of USQ students are enrolled in distance/online mode, while both SUT¹ and USC offer teaching to their cohorts entirely in traditional face-to-face

¹ SUT has a large number of students studying statistics online via Open Universities Australia and Swinburne Online, however StatsCasts currently focus on engineering students who are taught statistics entirely face-to-face.

mode. This diversity highlighted a number of challenges facing the research team – which concepts to present in the StatsCasts, how to present the concepts and what terminology to use.

This paper first introduces StatsCasts and describes the collaboration between the three universities leading to the production of these resources. It then reports on the evaluation of the initial phase of this collaborative research project which aims to investigate the strategies required for providing more flexible support to students of introductory statistics with the view to extending this support to other cohorts of students.

2. What are StatsCasts?

StatsCasts are screencasts (narrated recordings of handwritten explanation on a computer screen) that cover a variety of topics from statistics, basic research methodology, and how to use SPSS for statistical analysis. While screencasts may be recorded for a number of purposes (including full lecture content, supplementary support material which may broaden or deepen understanding, or to provide worked examples [15]), StatsCasts are primarily short, focussed video resources developed to explain concepts that may not have been fully understood in class. Initially, based on our many years of teaching introductory statistics, topics chosen for the StatsCasts reflect the concepts that our students have found difficult. In providing explanations of these concepts StatsCasts are segmented into clear steps within a relevant context in order to focus a student's attention, contain appropriate visuals to illustrate a concept to increase engagement with the content, and adopt a conversational style to promote engagement with the presenter [16,17].

It is recognised that difficult and often complex concepts, such as those perceived to be so by novice learners of statistics in introductory courses, may need to be revisited multiple times throughout a course [18]. Given that there is limited time in which to do this within the designated class time of an introductory statistics course, StatsCasts provide an alternative format for content revision. StatsCasts can complement the interactivity, dialogue and availability of immediate feedback that a face-to-face or real-time online “visit” to a mathematics support centre can provide. As such, StatsCasts deliver more flexible learning options to students outside fixed support centre opening hours but do not replace the support given by a tutor or regular class attendance. In fact, StatsCasts allow students to study statistical concepts from anywhere, on any internet connected device that can play videos, supporting the notion of mobile learning, which “offers educators a means to design learning activities and resources that allow students to individualise their learning” [9, p.220].

Although there is recognition of the benefits of screencasts, some criticism has been levelled at scientific screencasts, including that students are not challenged by bringing up and discussing common misconceptions and that they may be regarded as too passive a medium [20]. While it is acknowledged that screencasts do not allow students to verify their understanding in the traditional sense by obtaining immediate feedback from a tutor, there is a place for screencasts to supplement learning [21]. A study conducted by Loch, Jordan, Lowe and Mestel into the impact on performance in a quiz following the provision of screencasts to review calculus content demonstrated “the very significant effect of screencasts on those questions which are relevant to the screencasts” [21,p.9]. Provision of these additional explanations of concepts regarded as ‘troublesome knowledge’ may assist students to move forward from ‘stuck places’ particularly at times when they do not have easy access to immediate feedback from a

tutor [22]. We therefore argue that StatsCasts have a role to play in supporting statistical learning, and it is this role which is the focus of our research. Furthermore, in response to these reservations, we have specifically designed StatsCasts as short screencasts (the goal is to keep the maximum length near five minutes), maintaining a dynamic and more personal element [21] by adding handwritten annotations to the videos to keep students active in cognitive engagement [23].

3. Production of StatsCasts

StatsCasts are produced by tutors and lecturers at the three collaborating universities, with internal funding provided at one of these to pay a tutor to prepare recordings. The StatsCasts specifically discussed in this paper were produced in addition to the lecturer's normal workload to fill the void in flexible, anywhere, anytime support to his students. Topics chosen for inclusion in the StatsCasts reflect those usually covered in most introductory statistics courses – initially those of immediate relevance to his students. While there is common ground on required topics for the StatsCasts across all three universities, content and specific examples vary based on student needs, the focus of the introductory statistics courses being taught and the teaching experiences of those involved.

On the technical side, StatsCasts are produced following agreed specification guidelines to ensure they are compatible with each of the three universities' requirements of open educational resources. These include the format of the video, university branding, copyright/licensing, but also the provision of meta-data. The videos are produced in MP4 format, the current standard for iTunes U videos, which allows them to be played back on most video-enabled devices, including iDevices, as no Flash components are included. Since StatsCasts are developed as open educational resources, a Creative Commons licence (BY, ND, NC) is applied, which means that anyone can download them for free for non-commercial purposes (NC – non-commercial), provided they remain unchanged (ND – no derivatives) and authorship is acknowledged (BY). An agreement was reached between the marketing departments at all three universities to use the combined logo shown in Figure 1, designed by an SUT library staff member.

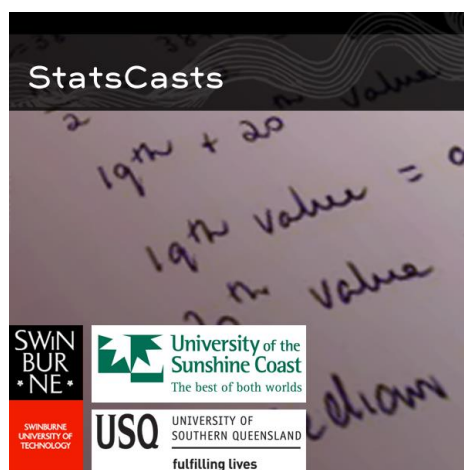


Figure 1. The StatsCasts logo

In addition, StatsCasts use similar front and end slides, tailored to the university that has produced the particular video; see Figure 2 for an example of the USC end slide. Since “discoverability” is vital for online resources, each StatsCast is provided with a set of meta-data, which includes not just the name of the narrator and the

university, but also classification as a StatsCast and the broad area of statistics that the video belongs to, such as inferential or descriptive statistics. The title, short description of content, and keywords related to the specific topic covered are also stored in the meta-data and included in the file when it is downloaded by a viewer.

StatsCasts differ from other online educational resources as they are internally peer-reviewed within the research group for quality control. Each video needs to be approved by at least one other colleague from the other two universities before it may be released outside the producing university. This peer-review process is taken seriously, with some StatsCasts being rejected, and others flagged for editing.

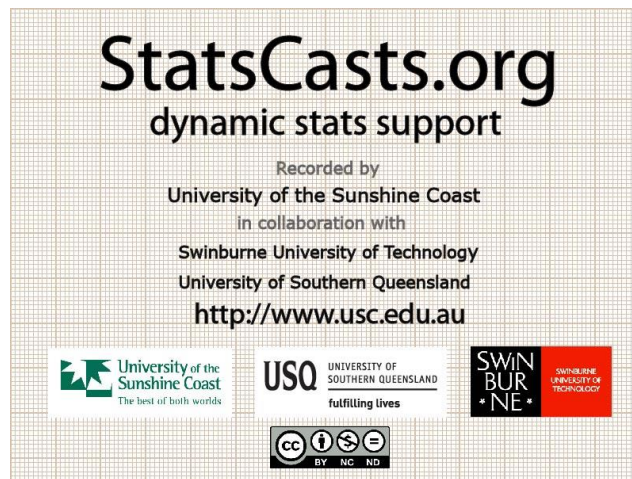


Figure 2. The end slide of a University of the Sunshine Coast StatsCast

StatsCasts are hosted by SUT via iTunes U and YouTube, but also on the project website <http://statscasts.org>. At this stage, only a small number of StatsCasts have been made publicly available, as focus of the project is on production for immediate local use and evaluation. Publication via the web will follow in the next few months.

For the interested reader, we share our workflow from conceptual idea to online StatsCast:

- (1) Selection of topic to record – generally one that was of most need to the students we currently teach
- (2) Selection of actual content for StatsCast and preparation of script
- (3) Recording of StatsCast, new entry in shared Google Drive spread sheet, listing all meta-data
- (4) StatsCast is shared with the other two universities via Dropbox for review
- (5) StatsCast is reviewed, any suggested edits are made
- (6) For StatsCasts that have passed peer-review, credit first and end slides are added, and the meta-data is included in the file
- (7) Upload to Dropbox to share with the Swinburne Commons team responsible for iTunes U and YouTube publication. StatsCast is flagged on Google Drive spread sheet as ready to publish
- (8) StatsCast is published, and Google Drive spread sheet updated by Commons team to reflect publication.

Following production and local release of the initial USC StatsCasts, the first phase of the research project was to conduct a preliminary evaluation of the introduction of this type of support for first-year students studying statistics.

4. Methodology

In the overarching research project, the following research questions will be addressed:

- (1) What are the perceived benefits of accessing StatsCasts, by students and instructors?
- (2) How should StatsCasts be designed to maximize effectiveness?
- (3) What factors encourage students to use StatsCasts to support their learning?
- (4) How are students using StatsCasts to study statistics (e.g., while travelling on mobile device; while studying with other students; to prepare for an assignment or examination)?

In this pilot stage of the research project, only the first question will be discussed in depth. Further examination of this and the remaining three questions will be considered in the continuing investigation beyond this pilot stage.

This study was conducted at the University of the Sunshine Coast (USC), a small Australian regional university (about 8900 enrolments in 2013). The students involved in this study were all enrolled in the course SCI110 *Science Research Methods*, a course that introduces research methodology and statistical concepts. In 2013, 924 students in SCI110 were enrolled, in disciplines such as biomedical science, engineering, environmental health, environmental science, health promotion, nutrition and dietetics, occupational therapy, paramedic science, and sport and exercise science. For all students, SCI110 is a required course in their program, usually in their very first semester at university, so many students are not intrinsically motivated to engage with the course. Thirteen StatsCasts were made available to these students with each screencast being uploaded into the learning management system following presentation of related content in lectures and tutorials (see Table 1 for details on topics, durations of the screencasts, and the number of responses related to viewing each screencast). Students were encouraged to watch the recordings as part of their studies. A short anonymous online survey was conducted asking students to identify which StatsCasts they had watched, how helpful they found the StatsCast (very helpful, a little helpful, a little unhelpful, or very unhelpful), and to give a comment. While it is not possible to distinguish the number of individual students who responded to the survey due to anonymity, the number of views of each screencast by respondents to the survey can be identified in all but seven instances. The responses ($N=555$) across the 13 screencasts were grouped according to how students responded to this question, and a thematic analysis of their comments was performed to gain further understanding of their views.

Table 1. Number of responses by StatsCast viewed ($N= 555$)

StatsCast topic	Duration	Responses	StatsCast topic	Duration	Responses
Creating Research Questions	3m 34s	52	Confidence Interval for one mean	4m 48s	40
Identifying Experimental units / Observational units	3m 23s	56	Sample size for means	4m 9s	34
Study Design	5m 45s	78	Sample size for proportions	3m 26s	36
Constructing Graphics	5m 6s	47	Paired t tests	5m 0s	11

Understanding boxplots	3m 56s	56	Two sample test for means	10m 24s	8
Tables / Chi-square tests	5m 19s	55	How to select an appropriate test	4m 58s	12
Odds / Odds ratio	4m 47s	63	Not identifiable		7

5. Preliminary evaluation

Of the 555 responses, 497 (90%) indicated that the specific StatsCast watched was “very helpful”, 48 (9%) indicated it was “a little helpful”, and 10 (2%) indicated it was “very unhelpful”. There were no responses of “a little unhelpful.”

Of the 497 responses that indicated the StatsCasts were “very helpful”, 144 did not include a comment. While many comments provided in the remaining responses acknowledged that the StatsCasts were “great” or said “thank you,” indications of how the StatsCasts were useful could generally be classified as: (i) useful for revision, (ii) clarifying concepts, (iii) confirming understanding of concepts, (iv) giving the option of watching at their own pace, (v) adding value to visual learners, and (vi) viewing saved time compared with reading (see Table 2 for a sample of typical comments). Students also appreciated that the StatsCasts were clear, concise and to the point. One student who had missed a couple of lectures commented that “the StatsCasts were very helpful in catching up on what I had missed.”

Table 2. Sample comments on how the StatsCasts contributed for “very helpful” group

Category	Sample Comments
Revision	“The statscasts are so helpful and perfect for refreshing memory, revision and taking note of the important aspects of a lecture.” “It was great as revision after covering these topics in the lecture.”
Clarification	“Very helpful to listen to when you get stuck” “I hadn’t understood this until I watched the Statscast” “helped to clarify terminology and give examples”
Confirm understanding	“Good to be able to confirm what ive (sic) learnt” “It is good to get little reminders about the content of this course as there is so much to take in.”
Own pace	“I can pause, print, replay what and when I want.” “helps to really understand because you can download them and keep watching as much as you need”
Visual learner	“Visually showed what was being done” “Its better for visual learners cause reading about [it] usually doesn’t help as much.”
Time saving	“They were clear and concise. Much more useful than hunting through pages of slides from lecture notes.” “saved me hours”

Forty-eight responses indicated that the StatsCasts were “a little helpful.” Of these, 35 (73%) responses referred to issues related to either still being confused, already being proficient with the content, requested more examples, or offered positive remarks (see Table 3 for sample comments). Of the remaining thirteen responses, two referred to technical issues and included that there was a preference for drop-in sessions where questions could be asked; three indicated the screencasts were more than “a little

helpful” but not as much as “very helpful,” but no such category was available, with two of these responses adding that more explanation was needed; eight did not comment.

Table 3. Sample comments for “a little helpful” group

Category	Sample Comments
Still confused	“not the statscasts fault. Still grappling with the concepts. May become very helpful down the track.” “still a little confused , more reading and watching may help. penny hasn't dropped yet.”
Already proficient	“I was already pretty comfortable with this but just wanted to check.” “pretty much had this one under control anyway from watching the lecture, but every little bit helps”
More examples	“more examples would of (sic) helped more.” “I think it would be beneficial to have examples containing relational/comparative RQ's.”
Satisfied	“utilised as part of my study is helping me understand the subject” “A good straight forward explanation”

Of the ten responses indicating that the StatsCasts were “very unhelpful” one referred to technical issues with downloading the files and the other nine did not include a comment. These ten responses came from at most 4 individual students.

The overall perception of the StatsCasts by students was positive, with most students indicating that they were beneficial to their learning and understanding of the relevant concepts. In this initial evaluation it appears that the StatsCasts were mainly used for revising concepts that had already been covered in class. Where the StatsCasts may have not satisfied expectations was in providing more examples or where a student needed to do more work on the topic before full understanding could be achieved.

6. Discussion, conclusions and ongoing work

6.1. Discussion

While StatsCasts are primarily being produced for students at SUT, USC and USQ, it is believed that they will be of benefit to a wider audience. The focus is on providing supplemental explanations of key concepts covered within introductory statistics courses, and as such cannot be expected to provide a comprehensive view of the content of any introductory statistics course. While some students indicated that they wanted more examples discussed within a StatsCast, others appreciated the succinct explanations given. By their very nature, the StatsCasts were not designed to provide lots of examples on any one topic as this would have been at the expense of keeping them short and concise to reduce cognitive load and keep students engaged. Furthermore, extra examples are generally furnished in lectures and tutorials. StatsCasts are intended to be ancillary to this content.

Early on in the project it was realised that due to the diversity in requirements within the three collaborating universities, there is, at times, a need to produce more than one screencast for each commonly-included topic in introductory statistics. Some courses have a greater emphasis on mathematical aspects than others. For some there is a greater need for procedural explanations with worked examples in addition to the more conceptual discussion, whereas for others the more mathematical aspects are downplayed in favour of a stronger emphasis on conceptual understanding.

One key aspect to the production of StatsCasts was to keep them short. This may have implications for the selection of topics, including concepts and procedures, which should be included in the StatsCasts collection. Screencasts of topics that do not lend themselves to being broken down into short explanations, while still useful, may need to be identified as being longer and possibly separated from the main collection.

With limited technical resources the development team has concentrated their efforts on applying appropriate pedagogical content knowledge, using correct statistical language, and writing with consistent statistical notation. To this end, careful scripting of each StatsCast prior to recording is implemented to maintain quality. This can be very time consuming, however it is anticipated that the reusability of these resources in providing flexible access to support by students learning introductory statistics will balance this cost.

6.2. Conclusion

In this paper we discuss the development of StatsCasts including issues addressed by the research team in exploiting this type of support for learning. We present preliminary findings on the perceived benefits of accessing StatsCasts by students. With the diversity in student needs and content focus of introductory statistics courses (particularly in the level of mathematical content), the purpose of each StatsCast needs to be explicitly stated at the outset so that students can obtain maximum benefit from accessing this type of support.

6.3. Ongoing work

Further investigations will include how to effectively present relevant information on the website about the content of each StatsCast and how the StatsCasts link together to give comprehensive ancillary support for learning introductory statistics. For the next phase of the project students will be invited to participate in a more comprehensive online survey based on a MathsCasts survey held at SUT [24]. In this survey students will be asked how StatsCasts could be improved (e.g., technical quality, content selection, style of explanation) but also how students engage with the StatsCasts. This feedback will then influence the design of the next round of StatsCasts and help find answers to the four research questions we have stated earlier.

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References

- [1] S. Tishkovskaya and G.A. Lancaster, *Statistical Education in the 21st Century: a Review of Challenges, Teaching Innovations and Strategies for Reform*. Journal of Statistics Education. 20 (2012), pp. 1–55.
- [2] S. Britton, D. Daners and M. Stewart, *A self-assessment test for incoming students*. Int J Math Educ Sci Technol. 38 (2007), pp. 861–868.
- [3] T.M. Wilson and H. MacGillivray, *Counting on the basics: mathematical skills among tertiary entrants*. Int J Math Educ Sci Technol. 38 (2007), pp. 19–41.
- [4] L.J. Rylands and C. Coady. *Performance of students with weak mathematics in first-year mathematics and science*. Int J Math Educ Sci Technol. 40 (2009), pp. 741–753.
- [5] N. Jourdan, P. Cretchley and T. Passmore. *Secondary–tertiary transition: what mathematics skills can and should we expect this decade?* In: J. Watson and K. Beswick,

- editors. *Mathematics: Essential Research, Essential Practice—Volume 2. Proceedings of the 30th Annual Conference of the Mathematics Education Research Group of Australasia.* (2007).
- [6] S.R. Belward, D.F.T Mullamphy, W.W. Read and G.E. Sneddon. *Preparation of students for tertiary studies requiring mathematics.* In: A. Stacey, B. Blyth, J. Shepherd and A.J. Roberts, editors. *Proceedings of the 7th Biennial Engineering Mathematics and Applications Conference, EMAC-2005, ANZIAM J.* 47 (2007).
 - [7] A.J. Onwuegbuzie. *Modeling statistics achievement among graduate students.* *Educational and Psychological Measurement.* 63 (2003), pp. 1020–1038.
 - [8] R.N. Lalonde and R.C. Gardner. *Statistics as a second language? A model for predicting performance in psychology students.* *Canadian Journal of Behavioural Science.* 25 (1993), pp. 108–125.
 - [9] A.J. Onwuegbuzie. *Writing a research proposal: The role of library anxiety, statistics anxiety, and composition anxiety.* *Library & Information Science Research.* 19 (1997), pp. 5–33.
 - [10] M. Zeidner. *Statistics and mathematics anxiety in social science students: some interesting parallels.* *British Journal of Educational Psychology.* 61 (1997), pp. 319–328.
 - [11] H. MacGillivray. *Learning support and students studying mathematics and statistics.* *Int J Math Educ Sci Technol.* 40 (2009), pp. 455–472.
 - [12] H. MacGillivray and T. Croft. *Understanding evaluation of learning support in mathematics and statistics.* *Int J Math Educ Sci Technol.* 42 (2011), pp. 189–212.
 - [13] B. Loch, A.C. Croft and O. Gill. *MathsCasts – enhancing the resource base for mathematics support centres.* In: P. Rowelett, editor. *Media enhanced teaching and learning: case studies and evidence of effective use.* *Mathematical Sciences HE Curriculum Innovation Project, UK.* (2012).
 - [14] B. Loch, O. Gill and A.C. Croft. *Complementing mathematics support with online MathsCasts.* *ANZIAM J. (EMAC2011).* 53 (2012), pp. 561–575.
 - [15] R.H. Kay. *A model for creating effective instructional video podcasts.* Paper presented at Global Learn 2012. Available from: <http://www.editlib.org/p/42039>.
 - [16] R. Kay and I. Kletskin. *Evaluating the use of problem-based video podcasts to teach mathematics in higher education.* *Computers & Education.* 59 (2012), pp. 619–627.
 - [17] A.A. Carvalho, C. Aguiar, H. Santos, L. Oliveira, M. Aldina and R. Maciel. *Podcasts in higher education: students' and lecturers' perspectives.* In: A. Tatnall and A. Jones, editors. *Education and technology for a better world. Proceedings of the 9th IFIP TC 3 World Conference on Computers in Education, WCCE 2009 July 27-31; Bento Gonçalves, Brazil.* (2009).
 - [18] A. Zieffler, J. Garfield, S. Alt, D. Dupuis, K. Holleque and B. Chang. *What does research suggest about the teaching and learning of introductory statistics at the college level? A review of the literature.* *Journal of Statistics Education.* 16 (2008), pp. 1–25.
 - [19] C. Sutton-Brady, K.M. Scott, L. Taylor, G. Carabetta and S. Clark. *The value of using short-format podcasts to enhance learning and teaching.* *ALT-J, Research in Learning Technology.* 17 (2009), pp. 219–232.
 - [20] D. Muller, J. Bewes, M. Sharma and P. Reimann. *Saying the wrong thing: improving learning with multimedia by including misconceptions.* *Journal of Computer Assisted Learning.* 24 (2008), pp. 144–155.
 - [21] B Loch, C. Jordan, T. Lowe and B. Mestel. *Do screencasts help to revise prerequisite mathematics? An investigation of student performance and perception.* *Int J Math Educ Sci Technol.* (2013), DOI: 10.1080/0020739X.2013.822581.
 - [22] J.H.F. Meyer and R. Land. *Threshold concepts and troublesome knowledge (2): epistemological considerations and a conceptual framework for teaching and learning.* *Higher Education.* 49 (2005), pp. 373–388.
 - [23] R.E Mayer. *The promise of multimedia learning: using the same instructional design methods across different media.* *Learning and Instruction.* 13 (2003), pp. 125–139.

- [24] C. McLoughlin and B. Loch. *Scaffolding conceptual learning in mathematics with technology enhanced pedagogy – a preliminary evaluation of student engagement with screencasts*. Paper presented at the World Conference on Educational Multimedia, Hypermedia and Telecommunications, (2013), Victoria, Canada. Available from <http://www.editlib.org/p/11967>.
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